TI: Field Evidence of Unstable Infiltration into Variably Saturated Fractured Basalt on a 1-Meter Scale

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AB: Understanding mechanisms of water flow and contaminant transport in a fractured basalt vadose zone at a small field scale is critical for developing conceptual and mathematical models of migration of organic, inorganic and radioactive contaminants. A number of United States Department of Energy (DOE) waste disposal sites are situated in geologic provinces with fractured rocks. Several sites have intermittently detected organic and radioactive contaminants in groundwater, which were not expected or predicted using conventional models for contaminant migration through the vadose zone. In an attempt to gain a better understanding of the water flow and transport processes, we conducted five one-meter-scale ponded infiltration tests during 1998 and 1999 to study the infiltration processes in partially saturated fractured basalt. An infiltration gallery was installed over a surface-exposed fracture on the top of a basalt column. Three different ponding conditions were applied in the infiltration gallery, including constant, stepped-variable, and periodic-falling hydraulic heads. The infiltration rates measured during the tests were highly variable with time and were apparently unrelated to the head in the infiltration gallery, tensiometric pressures and temperature in the basalt matrix and fractures, as well as barometric pressure. Measurements of the water outflow at the fracture exit were conducted to determine the water dripping rate and mass outflow at several locations. The data analysis showed that the dripping and mass outflow rates exhibited unstable and nonperiodic chaotic behavior with low- and high-frequency temporal and spatial fluctuations, which appear to be unrelated to the inflow rate and the tensiometric pressure gradient. We suggest that an important feature of flow in a fractured basalt vadose zone is that the hydraulic system may include both unsaturated and saturated components. However, the saturated zones have a limited, local extent within flow channels in the fractures and vesicular zones, whereas the surrounding basalt matrix may remain unsaturated. The complex interaction of multiple, inherently nonlinear processes in both the fracture and matrix may lead to the observed flow instabilities, which cannot be described using the classical paradigms for fluid flow in a fractured rock vadose zone.